Laboratories for the 21st Century: Best Practice Guide

Metrics and Benchmarks for Energy Efficiency in Laboratories

1 Introduction

1.1 Purpose of this Guide

A wide spectrum of laboratory owners, ranging from universities to federal agencies, have explicit goals for energy efficiency in their facilities. For example, the Energy Policy Act of 2005 (EPACT 2005) requires all new federal buildings to exceed ASHRAE 90.1-2004 [1] by at least 30 percent. The University of California Regents Policy requires all new construction to exceed California Title 24 [2] by at least 20 percent.

A new laboratory is much more likely to meet energy efficiency goals if quantitative metrics and targets are explicitly specified in programming documents and tracked during the course of the delivery process. If efficiency targets are not explicitly and properly defined, any additional capital costs or design time associated with attaining higher efficiencies can be difficult to justify.

The purpose of this guide is to provide guidance on how to specify and compute energy efficiency metrics and benchmarks for laboratories, at the whole building as well as the system level. The information in this guide can be used to incorporate quantitative metrics and targets into the programming of new laboratory facilities. Many of these metrics can also be applied to evaluate existing facilities. For information on strategies and technologies to achieve energy efficiency, the reader is referred to Labs21 resources, including technology best practice guides, case studies, and the design guide (available at www.labs21century.gov/toolkit).

1.2 Definitions

Metric: a unit of measure that can be used to assess a facility, system, or component; e.g., W/sf lighting power density (LPD).

Benchmark: a particular value of a metric that denotes a level of performance; e.g., California Title 24 allows 1.3 W/sf LPD for laboratory spaces.

1.3 Structure of this Guide

Section 2 deals with whole-building metrics and benchmarks

Sections 3-6 provide key metrics and benchmarks for ventilation, heating and cooling, process loads, and lighting, respectively.

For each metric, we provide a definition, one or more benchmarks, and data from the Labs21 benchmarking database or other sources. We also indicate how the metric can be used to assess the potential for specific energy efficiency opportunities.

Finally, section 7 provides process guidance on how to specify and track metrics over the course of design, delivery, and operation.

EPA United States Environmental Protection Agency

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Federal Energy Management Program

2 Whole-Building Metrics

2.1 Metrics based on ASHRAE 90.1

ASHRAE Standard 90.1 is increasingly being used to assess the energy efficiency of laboratories during the design phase—especially those projects seeking a LEED rating. Typically, this involves setting goals relative to the performance of a baseline building, as defined in the standard. In practice, however, simply specifying a goal of "x% better than ASHRAE 90.1" is inadequate because it leaves several key factors open to interpretation, which in turn will affect the meaning of the percentage reduction goals. Therefore, it is recommended that owners and designers further qualify this metric by specifically addressing and clarifying the following factors:

Appendix G vs. Section 11: An important consideration with regard to the use of ASHRAE 90.1-2004 is whether to use Appendix G rather than Section 11 for calculating savings. While both are performance-based, there are some variations in how the baseline performance is determined. The advantages to using Appendix G include:

- It is specifically designed for quantifying improvements beyond the standard. (In contrast, Section 11 is designed for checking minimum compliance.)
- The baseline does not change with different proposed system selections.
- It is required by LEED-NC 2.2 for any project seeking to achieve energy-efficiency credits.

On the other hand, some of the disadvantages are that:

- At the time of this writing, it is not officially a part of the ASHRAE standard—it is an informative appendix. As a result, meeting the requirements of appendix G does not equate to compliance with the standard. However, it is anticipated that it will be approved as a normative appendix shortly.
- It requires more modeling work than Section 11.

On balance, it is recommended that Appendix G be used as the basis for performance evaluation goal setting.

Labs21 Modeling Guidelines: These guidelines[3] were developed to clarify or modify selected sections of the ASHRAE 90.1 standard in order to make them more applicable to systems serving laboratory spaces. Table 1 summarizes the modifications in the Labs21 guidelines.

While the Labs21 guidelines are designed to be used in conjunction with Appendix G of the standard, they were developed by Labs21 and are not officially a part of the standard. However, it is anticipated that most of the key provisions will be incorporated into the standard through "continuous maintenance" proposals. As of this writing, the fan power limitation has been addressed through Addendum ac, which will be incorporated into the 2007 version of the standard. To the extent that other elements in the guidelines are not yet part of the standard, it is recommended that they be followed when modeling laboratory buildings.

Table 1. Issues addressed by the Labs21 Modeling Guidelines

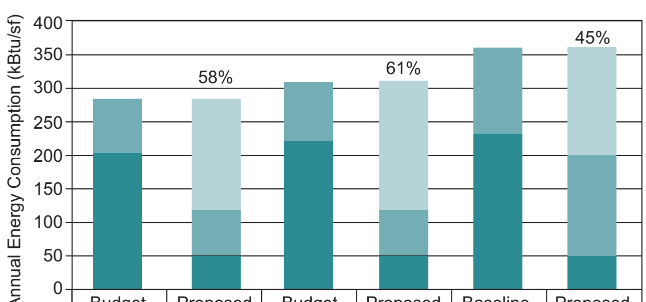
Guideline Area	ASHRAE 90.1 sections being modified	Intent and rationale for modification
I. Baseline HVAC system type and energy recovery	6.5.7.2 Fume Hoods G3.1.1 Baseline HVAC System Type and Description Table G3.1.1A Baseline HVAC System Types G3.1.2.10 Exhaust Air Energy Recovery	Clarify that a baseline building must have either a VAV system OR energy recovery, but not both. This provision applies to all laboratory air handling systems, not just systems serving fume hoods.
II. Laboratory fan power limitation	6.5.3.1 Fan Power Limitation G3.1.2.9 Fan Power	Increase the allowable fan power limitations. While the standard provides pressure credits for filtering systems, heat recovery, etc., laboratory fan systems typically exceed the fan limitations even with these credits.
III. Modeling load diversity and reheat energy impacts	Table G3.1 No.4 Schedules (new) G3.1.3.16 Supply-Air-to-Room Air Temperature Difference	Ensure that reheat energy use due to internal equipment load variations is properly modeled. Labs have large variations of internal equipment loads from one space to the next—this has a substantial impact on reheat energy use.

Baseline for percentage reduction: There are two commonly used ways to express percentage reduction:

1. percentage reduction relative to total loads (including process loads)
2. percentage reduction relative to "regulated loads" (excluding process loads)

Appendix G of the 2004 version specifies the first approach (i.e., based on total loads). Earlier versions of LEED-NC (prior to 2.2) followed the second approach. This often created confusion about what was included or excluded in the percentage calculation, and was especially problematic in laboratory buildings. For example, fume hoods were sometimes included because they were part of the HVAC system, and other times excluded because they were considered a process load. Figure 1 compares different options for calculating percentage reduction for the Science and Technology Facility at the National Renewable Energy Laboratory, which received a LEED-NC Platinum rating. The difference between the options underscores the need to clearly define how it is calculated and compared with other facilities.

While percentage reduction of total load is the primary metric that should be used, it is also useful to track percentage reduction of regulated loads, since it provides a measure of the efficiency of features that designers have significant control over. This is particularly true in laboratories, where process loads can vary significantly across different projects and design estimates are often grossly inaccurate.



	Budget Model (90.1-1999 ECB)	Proposed Model (90.1-1999 ECB) & Savings	Budget Model (Labs21 1999 ECB)	Proposed Model (90.1-1999 ECB) & Savings	Baseline Model (90.1-2004 App. G)	Proposed Model (90.1-2004 App. G) & Savings
Savings %		58%		61%		45%
Savings	0	164	0	188	0	161
Electricity	80	70	87	70	128	150
Gas	204	50	222	50	233	50

Figure 1. Different options to calculate percentage reduction—results for the Science and Technology Facility at the National Renewable Energy Laboratory. Source: NREL/AEC.

Metric for percentage reduction: ASHRAE 90.1 requires that energy cost be used as the metric for calculating percentage reduction. EPACT 2005, on the other hand, uses site energy as the metric for savings calculation. The percentage reduction for site energy, source energy, and cost will be different depending on the rate structure and fuel mix. If projects seek to set and track energy and emissions goals, it is important to track percentage reduction results using both cost and source energy metrics. (This is a minimal additional burden since most energy modeling tools provide both metrics in their output.) Traditionally, energy cost has served as a reasonably good proxy for source energy. However, recent and anticipated volatility in the natural gas and electricity markets may make this assumption invalid.

Modeling assumptions sensitivity analysis: Energy modeling always requires making a host of assumptions, either because some parameters are unknown, or because the modeling tool does not directly support certain building features. As a result, many building owners and designers are concerned about the validity of modeling results. The following recommendations can help to mitigate this issue:

- Select experienced modelers: Energy modeling is a highly specialized skill, and owners and designers should select modelers that have experience with laboratories.
- Understand key assumptions: Modelers should document the key assumptions and review them with designers to ensure that they are valid.
- Test the sensitivity of key assumptions: Modelers should run parametric variations on the key assumptions and document the sensitivity of the results to variations in the assumptions.

2.2 Metrics based on empirical performance

While metrics based on ASHRAE 90.1 are useful for exploring design alternatives, many owners and designers are uncomfortable with the wide variability in modeling results. Some projects are now looking to define an explicit energy use target that the design should meet—which also serves as a reality check for the modeled results. In the case of office buildings, for example, owners can specify that they should be designed to earn an Energy Star label. However, Energy Star does not have a comparable rating system for laboratories. For labs, there are two options for setting a target:

- For organizations that have energy use data on a portfolio of laboratory buildings, targets could be set based on the range of energy use intensity across the portfolio.

- Based on the Labs21 energy benchmarking database.

In both cases, the comparison set of buildings should have similar climatic context and lab-area ratio (ratio of net lab area to gross building area), or otherwise correct for these factors. For example, Figure 2 shows the comparison set containing energy use data from laboratories in the San Francisco Bay Area, with a lab-area ratio in the range of 40–60 percent. Thus, a new laboratory may, for example, set a target corresponding to the 1st quartile; i.e., 375,000 BTU / sf-yr of site energy use.

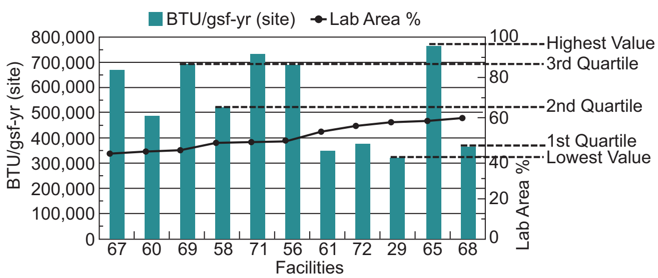


Figure 2. Empirical benchmarking data from Labs21 database for laboratories with lab area ratio between 0.4-0.6 and located in the warm marine climate zone (e.g., San Francisco).

The whole-building metrics discussed above are useful in assessing the overall efficiency level for a building. The next few sections describe system-level metrics that can be used to identify specific opportunities for efficiency improvement.

3 Ventilation Metrics

3.1 Minimum required ventilation rate

Ventilation dominates energy use in most laboratories, especially chemical and biological laboratories. One of the key drivers of ventilation energy use is the minimum ventilation rate required for health and safety. The only exceptions to this are laboratories where the air-change rates are driven by thermal loads (and hence always exceed minimum ventilation rates for health and safety) or where very high fume hood density, typically greater than 1 square foot of hood work surface per 25 gross square feet of laboratory, drives the minimum flow. The purpose of benchmarking minimum ventilation rates is to explore opportunities for optimization. Specifically, optimization in this context means reducing air-change rates while maintaining or improving safety. Air-change rates should be benchmarked with two metrics:

Air changes per hour (ACH): This is the most commonly used metric. Various standards and guidelines indicate that this can vary between 4 and 12, which is a very large range. Table 2 shows the range of values listed in various standards. Values higher than 6 ACH (when occupied) and 4 ACH (unoccupied) should be explicitly justified as being required for health and safety.

CFM / sf: Some laboratory professionals believe that this is a more appropriate metric, given that laboratory hazards are more related to floor area than volume; i.e., a laboratory with a high ceiling does not necessarily require more ventilation. The International Building Code (2003) requires a rate of 1 cfm / sf for H-5 hazard environments.

Table 2. Air-change rates recommended in various standards and selected projects [4]

Standard/Guideline	**Recommended Air-Change Rate**
ANSI/AIHA Z9.5-2003 [5]	The specific room ventilation rate shall be established or agreed upon by the owner or his/her designee.
NFPA-45-2004 [6]	Minimum 4 ACH unoccupied, occupied “typically greater than 8 ACH.”
ACGIH Ind. Vent 24th Ed., 2001 [7]	The required ventilation depends on the generation rate and toxicity of the contaminant—not on the size of the room in which it occurs.
ASHRAE Lab Guide-2001 [8]	4-12
OSHA 29 CFR Part 1910-1450 [9]	4-12
Project	**Specified Air-Change Rate**
UC Santa Cruz Bio-Med Building	6 ACH occupied, 4 ACH unoccupied
UC Davis Tahoe Center	6 ACH occupied, 4 ACH unoccupied in low-risk labs
UC Berkeley Li-Kashing Building	6 ACH

3.2 Hood density

Fume hoods are prodigious consumers of energy and lab planners should work with owners to carefully avoid installing more and larger hoods than are necessary for programmatic requirements. Specifically, fume hoods should not be used for purposes that can be effectively met with lower-energy alternatives such as snorkels, balance hoods, and chemical storage cabinets. It is recommended that fume-hood density should be benchmarked with other labs that have similar programmatic requirements. For example, Figure 3 shows the range of fume-hood density (expressed as number of hoods/5000 gross square feet) in various laboratories in the UC/CSU system. Based on this chart, values higher than about 3 hoods/5000 gsf may present opportunities for optimizing the number of fume hoods.

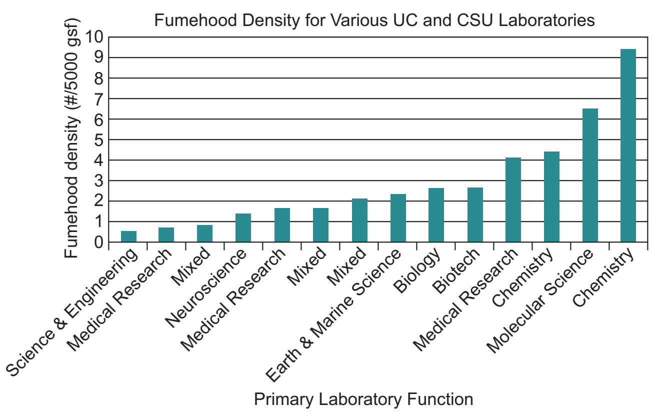


Figure 3. Fume-hood density for selected academic laboratories across the University of California and California State University. Data source: UC/CSU/IOU Monitoring-based Commissioning Program.

3.3 Fume hood sash management

Once the number and size of fume hoods has been optimized, the next major opportunity is to reduce fume hood energy use by reducing airflow through low-volume fume hoods and VAV hoods with effective sash management (a major retro-commissioning opportunity).

While there are no commonly used metrics for sash management, we suggest using <u>fume hood airflow management ratio</u>, defined as the ratio of the average flow to the minimum flow. Minimum flow is the flow through the fume hood when the sash is closed. For a typical 6-ft fume hood, this is usually about 300 cfm (which corresponds to the NFPA-45 mandated minimum of 25 cfm/sf of work surface area). A typical 6-ft fume hood with an 18" sash-stop operates at about 900 cfm. Therefore, if the sash were never closed, the airflow management ratio would be 3. If the sash were closed 50 percent of the time, the ratio would be 2.

Figure 4 shows the impact of sash management training on airflow management ratios for a laboratory at Duke University, indicating a significant improvement in sash management as a result of the training and awareness campaign.

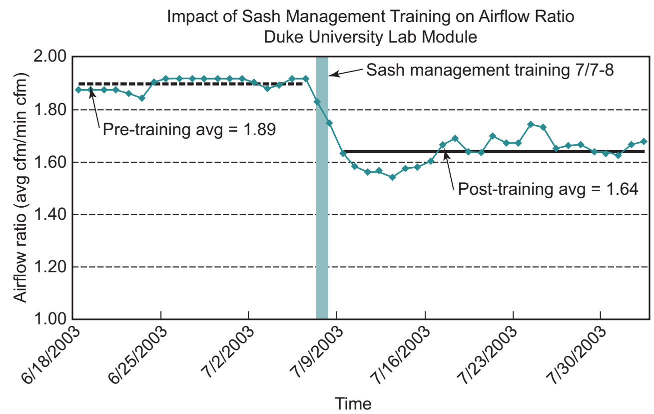


Figure 4. Impact of sash management training on airflow management ratios for a laboratory at Duke University. The airflow with sash open was 650 cfm, and with sash closed was 340 cfm. Therefore, the airflow ratio if sashes were never closed would have been 1.91.

3.4 Ventilation airflow efficiency

Ventilation airflow efficiency is typically the most significant way that HVAC design engineers can influence overall lab efficiency. There are two key related metrics:

<u>Pressure drop (in. w.g.)</u>: Each component in the supply and exhaust system can be optimized for low pressure drop. Table 3 compares typical practice with low pressure drop design for the Tahoe Center for Environmental Studies, which received a LEED Platinum rating. (Additional information on low pressure drop benchmarks and design guidelines are described by Weale et al.[10] and Labs21 [11])

<u>Ventilation system W/cfm</u>: This metric is defined as the total power of supply and exhaust fans divided by the total cfm of supply and exhaust fans. It provides an overall measure of how efficiently air is moved through the laboratory, from inlet to exhaust, and takes into account low pressure drop design as well as fan system efficiency (motors, belts, drives). Figure 5 shows the range of ventilation system efficiency at peak loads for various laboratories in the Labs21 benchmarking database. There is a wide range of efficiencies, from 0.3 W/cfm to 1.9 W/cfm. The fan power limitations specified in ASHRAE 90.1 2004 provide an additional benchmark.

Table 3. Comparison of typical and low pressure drop design at the Tahoe Center for Environmental Studies at Sierra Nevada College.

	Typical	TCES—UC Davis
Air handling unit—Clean filters including system effect	2.2" w.g.	0.68" w.g.
Dirty Filter Allowance	1.3" w.g.	1.45" w.g.
Heat Recovery	0.5" w.g.	0.56" w.g.
Silencer	1.0" w.g.	0
Supply Duct Work, Diffusers	2.5" w.g.	0.65" w.g.
VAV device	0.5" w.g.	0.30" w.g.
Zone coils	0.4" w.g.	0.20" w.g.
Safety Factor	0.6" w.g.	0.60" w.g.
Total Supply	**9.0" w.g.**	**4.4" w.g.**
Hood	0.50" w.g.	0.50" w.g.
Flow Device	0.45" w.g.	0.30" w.g.
Exhaust Duct Work	2.00" w.g.	0.55" w.g.
Heat Recovery with filter	0.50" w.g.	0.50" w.g.
Exhaust Outlet (incl. velocity pressure)	0.70" w.g.	0.70" w.g.
Total Exhaust	**4.15" w.g.**	**2.55" w.g.**
Total Static Supply plus Exhaust	**13.15" w.g.**	**6.95" w.g.**

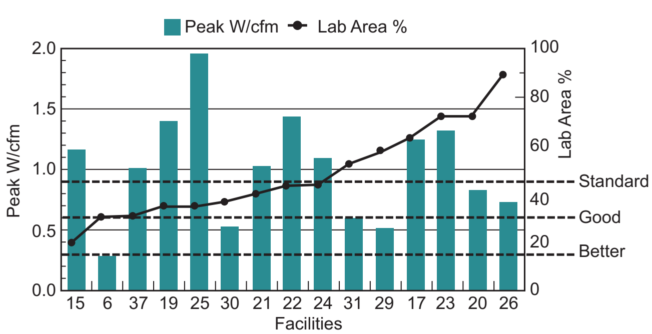


Figure 5. Ventilation system efficiency at peak conditions for various laboratory facilities in the Labs21 energy benchmarking database. The benchmarks for standard, good, and better practice are based on the Labs21 Best Practice Guide on Low Pressure Drop Design for Laboratories [11].

4 Cooling and Heating Metrics—Special Considerations for Labs

4.1 Temperature and humidity set points

Temperature and humidity set points in laboratory spaces are driven by human comfort and laboratory function (experimentation/equipment requirements). Laboratory users and planners sometimes call for tight tolerances based on laboratory function, without evaluating whether these are actually required. Tight tolerances can increase energy use due to reheat and humidification. It is recommended that tolerances tighter than those required for human comfort (e.g., based on ASHRAE Standard 55 [12]), be carefully evaluated and explicitly justified. At the Global Ecology Center at Stanford, equipment requiring tight tolerances (70F +/- 1F) was grouped into a dedicated area so that other areas of the lab could be controlled to wider tolerances (73F +/- 5F) with some rarely accessed freezers and growth chambers actually relocated to a minimally conditioned adjacent structure controlled to 55F–95F.

4.2 Heating and cooling system efficiency

The key metrics and benchmarks to evaluate the efficiency of chiller and boiler systems in labs are no different than those typically used in other commercial buildings. These include chiller plant efficiency (kW/ton), cooling load (tons/gsf), boiler efficiency (%), pumping efficiency (hp/gpm), etc. Since these are well-documented elsewhere, they are not discussed here and the reader is referred to other publications, such as ASHRAE Standard 90.1. However, two additional metrics have special impact on lab efficiency, and bear further discussion:

Chiller system minimum-turndown ratio: Laboratory systems are often oversized due to reliability/redundancy requirements, over-estimated process loads, or other factors. Even when systems are "right-sized", there are many hours when loads are much lower than peak. Therefore, chiller systems in labs should be designed for low minimum-turndown ratios, defined as the ratio of minimum load (with continuous compressor operation without hot gas bypass or other false loading methods) to design load. Standard practice would be about 20 percent. Good and better practice benchmarks would be 10 percent and 5 percent respectively. In the Molecular Foundry at Lawrence Berkeley National Laboratory (LBNL), the chiller system is capable of a 5 percent turndown ratio. In labs with tight humidity control, even lower ratios are warranted, unless alternative dehumidification strategies are adopted.

Reheat energy-use factor: Reheat energy use can be significant in labs. This can be due to tight temperature and humidity requirements, wide variation in loads served by a given air handling system [13], or poorly calibrated controls. While there is no well-established metric for assessing reheat energy use, we suggest a metric such as reheat energy-use factor, defined as the ratio of the reheat energy use to the total space heating energy use. The best practice benchmark for this would be 0 percent (i.e., complete elimination of reheat energy use for temperature control). The Koshland Integrated Natural Science Center at Haverford College achieves this by using dual heat wheels and separation of thermal and ventilation systems [14, 15].

5 Plug Load Metrics

Equipment loads in laboratories are frequently overestimated because designers often use estimates based on "nameplate" data, and design assumptions of high demand. This results in oversized HVAC systems, increased initial construction costs, and increased energy use due to inefficiencies at low part-load operation [16]. The following related metrics can be used to assess and compare design and measured plug loads:

Laboratory design plug load W/sf: The values may vary across lab spaces in a given building. Note that the assumption for electrical system design is usually higher than that for HVAC system design.

Laboratory actual (measured) plug load W/sf: This is obtained by taking continuous measurements at the panel serving laboratory plug loads. For HVAC system design, it is more appropriate to consider the maximum of the 15-minute interval averages (rather than maximum instantaneous load), since HVAC systems typically do not react to the instantaneous loads. For a building currently in design, it is recommended that measurements be taken in a comparable laboratory and those data be used for sizing.

Figure 6 compares the measured peak loads (maximum instantaneous and maximum 15-minute interval average) to the design loads for various laboratory spaces in a building at the University of California, Davis. While the sizing ratio is driven by context-specific factors such as reliability and flexibility, it is recommended that sizing factors greater than 2 be carefully evaluated and justified.

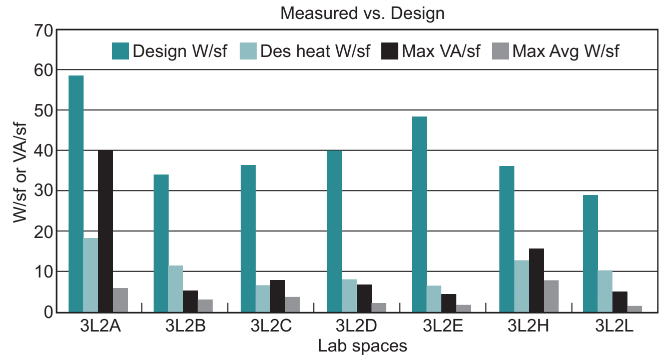


Figure 6. Comparison of design loads and measured plug loads in various laboratory spaces at the University of California, Davis. Measurements were taken over a 2-week period while labs were fully occupied. Des W/sf is the peak plug load assumption for electrical design. Des heat W/sf is the peak plug load assumption for HVAC design. Max VA/sf is the measured peak (instantaneous) apparent power. Max Avg W/sf is the maximum of the 15-minute averages.

6 Lighting Metrics

The key metrics and benchmarks to evaluate the efficiency of lighting systems in laboratories are not fundamentally different than those typically used in other commercial buildings. These include daylight factors, illuminance levels, lamp and ballast efficacy, lighting power density, etc. There are two key metrics for which the benchmarks in laboratories are different from other commercial buildings:

Task illuminance in laboratory spaces (fc): The 9th edition of the IESNA Handbook [17] has revised its illuminance recommendations for laboratories downward from the previous edition. The current recommendations are:

- Specimen collecting: 50 fc (horizontal), 10 fc (vertical)
- Science laboratory: 50 fc (horizontal), 30 fc (vertical)

Values higher than 50 fc should be carefully reviewed and justified by special functional requirements and should be restricted to the areas where the task is being performed. Furthermore, it is important to recognize that illuminance in and of itself is not an adequate measure of visual acuity, which is a function of several other factors, such as contrast ratios, color rendition, etc.

Installed lighting power density (W/nsf): This refers to the lighting power density in the laboratory spaces.

ASHRAE 90.1-2004 allows a maximum of 1.4 W/sf. The California Title 24 energy code allows a maximum of 1.3 W/sf. At the Tahoe Center for Environmental Studies, the laboratory spaces were designed to 0.80 W/sf.

7 How to Specify and Track Metrics—Process Considerations

The following are some key process considerations to specify and track metrics during design, delivery, and operation of laboratory buildings:

1. Identify metrics and set targets with stakeholder team. Metrics and targets are, in effect, key performance indicators for the quality of design and operation, and therefore should have the buy-in of all the key stakeholders (owners, designers, and operators). This could be done at project conception, and then refined during the early stages of the project. In the design for a new laboratory at LBNL, for example, a goal-setting meeting was held prior to conceptual design, in which the designers and owners considered a wide range of metrics, selected key metrics, and set targets for them. The list of metrics in Appendix A could be used as a template for identifying metrics and setting targets.

2. Incorporate key metrics and targets in programming documents. Designers and operators are much more likely to ensure that targets are met if they are officially incorporated into the programming documents.

3. Identify individual(s) responsible for tracking metrics. Ideally, the commissioning authority would have overall responsibility, since metrics are integral to the performance tracking and assurance process. However, various design professionals may have responsibility for computing individual metrics and providing these to the commissioning authority (e.g., lab planner for hoods/nsf, HVAC engineer for W/cfm, etc.)

4. Determine process and format for tracking and documenting metrics. The Labs21 Design Intent Tool can be used to track metrics and generate formatted reports in a consistent manner over the course of a project. Alternatively, project teams may develop their own formats based on the template provided in Appendix A.

8 Conclusion

Laboratories are much more likely to meet energy efficiency goals if quantitative metrics and targets are explicitly identified and tracked during the course of design, delivery, and operation.

This guide described key metrics and benchmarks at the whole building level as well as at the system level.

- While ASHRAE 90.1 can effectively be used as a basis for evaluating whole-building performance, it is recommended that it be used in conjunction with all the most recent addenda as well as the Labs21 modeling guidelines to address some lab-specific issues such as equipment load diversity and fan power limitations.
- It is strongly recommended that whole-building targets be evaluated against empirical benchmarks that are based on the measured energy use of peer facilities.
- Key ventilation system metrics include: minimum air-change rate (ACH, cfm/sf), hood density (hoods/nsf), hood airflow management ratio (Avg flow/min flow), system airflow efficiency (W/cfm).
- Heating, cooling, and lighting system efficiency metrics for laboratories are not significantly different from those used for other commercial buildings, although there are some special considerations for laboratories.
- Design assumptions for plug loads should be benchmarked against measured values in comparable laboratories.

Metrics and targets are, in effect, key performance indicators for the quality of design and operation, and therefore should have the buy-in of all the key stakeholders (owners, designers, and operators). The Labs21 Design Intent Tool can be used to document and track metrics over the project lifecycle.

References

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Appendix A: Laboratory Performance Metrics and Benchmarks

Laboratory Performance Metrics & Benchmarks

Notes
A performance Metric is a unit of measure used to assess performance (e.g. Ventilation W/cfm, Building Site Energy BTU/sf-yr).
A performance Benchmark is a particular value of the metric that is used as a point of comparison.
Priority levels: 1 - Must have (highlighted below); 2 - Important, subject to ease of data collection; 3 - nice to have if easy to collect
This spreadsheet is under continuous development. For comments and questions, contact: Paul Mathew (510) 486 5116 ; pamathew@lbl.gov

					Suggested Benchmarks			
ID	Name	Unit	Priority	Value	Standard Practice	Good Practice	Better Practice	Notes
Building								
B1	Building Site Energy Use Intensity	Site BTU/gsf-yr	1		Meet ASHRAE 90.1; 3rd quartile in Labs21 database	20% below 90.1; 2nd quartile in Labs21 database	30% below 90.1; 1st quartile in Labs21 database	Include central utilities
B2	Building Source Energy Use Intensity	Source BTU/gsf-yr	1		Meet ASHRAE 90.1; 3rd quartile in Labs21 database	20% below 90.1; 2nd quartile in Labs21 database	30% below 90.1; 1st quartile in Labs21 database	Include central utilities
B3	Building Purchased Energy Cost Intensity	Energy $/gsf-yr	2		Meet ASHRAE 90.1; 3rd quartile in Labs21 database	20% below 90.1; 2nd quartile in Labs21 database	30% below 90.1; 1st quartile in Labs21 database	Include central utilities
B4	Building Peak Electrical Load Intensity	Peak W/gsf	2		Meet ASHRAE 90.1; 3rd quartile in Labs21 database	20% below 90.1; 2nd quartile in Labs21 database	30% below 90.1; 1st quartile in Labs21 database	Include central utilities
B5	Lab Area Ratio (net lab /gross bldg)	-	1		N/A	N/A	N/A	
Ventilation System								
V1	Min Laboratory Ventilation Rate: Area-based	cfm/nsf	1		> 1		1 (justified if >1)	Subject to EH&S
V2	Min Laboratory Ventilation Rate: Volume-based	ACH	1		> 6 (occ & unocc)	> 6 (occ); <= 6 (unocc)	6 (occ), 4 (unocc)	Subject to EH&S
V3	Fumehood Density	hood-ft/nsf #hoods/nsf	2				Compare to similar labs	
V4	Overall Airflow Efficiency (sup&exh W/ sup&exh cfm)	W/cfm	1		0.9	0.6	0.3	Fans serving lab systems
V5	Total System Pressure Drop	in. w.g.	1		9.7	6.2	3.2	Total = supply+exhaust
V6	Fumehood Sash Mgmt (avg cfm/min cfm)	-	1		> 2	2.0 - 1.5	< 1.5	Aggregate for all fumehoods
V7	Ventilation Energy Use Intensity	kWh/gsf-yr	3		3rd quartile in Labs21 database	2nd quartile in Labs21 database	1st quartile in Labs21 database	Aggregate for all fans
Cooling System								
C1	Lab Temperature Deadband	F	1		70-74		Justified if tighter than ASHRAE 55	Indicate if unoccupied setback
C2	Lab Humidity Deadband	%	1		40-60		Justified if tighter than ASHRAE 55	Indicate if unoccupied setback
C3	Cooling System Efficiency	kW/ton	1		> 1.0		0.8	
C4	Chiller System Minimum Turndown Ratio	-	1		5 (20%)	10 (10%)	20 (5%)	Calculated from turndown ratios for individual chillers
C5	Chiller Efficiency	kW/ton	2		Meet ASHRAE 90.1	10% better than ASHRAE 90.1	20% better than ASHRAE 90.1	1 metric per chiller
C6	Chiller Rated Efficiency	NPLV kW/ton	2		Meet ASHRAE 90.1	10% better than ASHRAE 90.1	20% better than ASHRAE 90.1	1 metric per chiller
C7	Cooling Tower Efficiency	kW/ton	2					
C8	Cooling Tower Approach	F	2					
C9	Chilled Water Pumping Efficiency	W/gpm	2					
C10	Condenser Water Pumping Efficiency	W/gpm	2					
C11	Chilled Water Loop Delta T	F	2					1 for each building loop
C12	Water-Side Economizer Utilization Factor (if used)	%	2					load served by econ / total load
C13	Evaporative Cooling Utilization Factor (if used)	%	2					load served by evap / total load
C14	Cooling System Energy Use Intensity	kWh/gsf-yr	3		3rd quartile in Labs21 database	2nd quartile in Labs21 database	1st quartile in Labs21 database	
Heating System								
H1	Heating System Efficiency	-	1					output BTU/ input BTU for whole system
H2	Reheat Energy Use Factor	%	1		20%	5%	0%	reheat BTU/ total heat BTU
H3	Boiler Rated Efficiency	%	2		Meet ASHRAE 90.1		>90%	1 metric per boiler
H4	Boiler Part Load Efficiency	%	3		Meet ASHRAE 90.1		>90%	1 metric per boiler
H5	Energy Recovery System Utilization Factor (if used)	%	2				>90%	% of exhaust air flowing through device
H6	Energy Recovery Effectiveness (if used)	%	2		45 (sensible)	60 (sensible)	70 (total)	
H7	Energy Recovery Ratio (if used)	-	3					ratio of energy recovered (calculated from flows and temps) to total energy use
H8	Heating Energy Use Intensity	BTU/gsf-yr	3		3rd quartile in Labs21 database	2nd quartile in Labs21 database	1st quartile in Labs21 database	
Process Loads								
P1	Laboratory Design Plug-Load Intensity	W/nsf	1		10 - 25		Based on measured	Coincident for all labs in building
P2	Laboratory Measured Peak Plug-Load Intensity	W/nsf	1		2-15			Coincident for all labs in building
P3	Laboratory Plug-Load Sizing Ratio (design/measured)	-	1		>4		Justified if >2	Coincident for all labs in building
Lighting System								
L1	Laboratory Task Illuminance Design Setpoint	fc	1		80-100 (task+ambient)	Justified if >75	Justified if >50	1 metric per lab type
L2	Laboratory Ambient Illuminance Design Setpoint	fc	1		80-100 (task+ambient)		Justified if >30	1 metric per lab type
L3	Laboratory Lighting Installed Power Intensity	W/nsf	1		> 1.4	1.3	1.0	
L4	Daylight Utilization	%	2					% annual lighting met with daylight (by simulation)
L5	Laboratory Lighting Zone Size	sf	2				< 800	
L6	Laboratory Lighting Level Variation	#	3		2 (bi-level)	>2 (step)	>2 (cont.)	# of steps
L7	Lamp+Ballast Efficacy	lm/W	3		80		>90	1 metric per major fixture type - could aggregate?
L8	Laboratory Lighting Color Rendition	CRI	3		>70		>=85	1 metric per major lamp type
L9	Laboratory Lighting Color Temperature	K	3				4100-5000	1 metric per major lamp type
L10	Lighting Energy Use Intensity	kWh/gsf-yr	3		3rd quartile in Labs21 database	2nd quartile in Labs21 database	1st quartile in Labs21 database	

Acknowledgments

Author

Paul Mathew, Ph.D.
Lawrence Berkeley National Laboratory

Contributors and Reviewers

Dan Amon, P.E.
U.S. Environmental Protection Agency

William Lintner, P.E.
U.S. Department of Energy

Steve Greenberg, P.E.
Dale Sartor, P.E.
Lawrence Berkeley National Laboratory

Itzhak Maor, Ph.D., P.E.
PWI Consulting

Peter Rumsey, P.E.
John Weale, P.E.
Rumsey Engineers

Technical Editing and Layout

Bruce Balfour
Alice Ramirez
Creative Services Office (CSO)
Lawrence Berkeley National Laboratory

For More Information

On Metrics and Benchmarks for Laboratories

Paul Mathew, Ph.D.
Lawrence Berkeley National Laboratory
One Cyclotron Road, MS 90-3111
Berkeley, CA 94720
510-486-5116
PAMathew@lbl.gov

On Laboratories for the 21st Century

Dan Amon, P.E.
U.S. Environmental Protection Agency
1200 Pennsylvania Ave., N.W.
Washington, DC 20460
202-564-7509
amon.dan@epa.gov

William Lintner, P.E.
U.S. Department of Energy
Federal Energy Management Program
1000 Independence Ave., S.W.
Washington, DC 20585
202-586-3120
william.lintner@ee.doe.gov

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Prepared at the Lawrence Berkeley National Laboratory
A DOE national laboratory

October 2007

Printed with a renewable-source ink on paper containing at least
50% wastepaper, including 20% postconsumer waste